

of the tongue was lost, and with it the sensibility to taste of this part. Taste was intact in the anterior two-thirds.

3d. The ducts of the submaxillary and sublingual glands having been exposed in the manner described by Bernard, the function of these glands was found perfect.

Whence it appeared that the ninth pair exerts no influence on the secretory function of the submaxillary and sublingual glands, and that the filaments derived from the chorda tympani branch of the seventh pair, alone exert the nerve influences on the secretory function of these glands.

The writer also concludes, that since deglutition is performed equally well after section of the ninth pair or glosso-pharyngeal at its cerebral origin, the impression which leads to this action is due to the gustative or lingual branch of the fifth pair and not to the former as invariably alleged. Again, since section of the ninth pair at this point is attended by *no* disturbance of *motor power* the motor influence of this nerve, admitted in deglutition, must depend wholly upon the fibres of communication received from the *facial* (seventh) and *spinal accessory* (eleventh.)

J. T.

ART. XX.—1. *Croonian Lectures on Matter and Force*. Delivered at the Royal College of Physicians. By HENRY BENGE JONES, A. M., M. D., F. R. S. (*British Medical Journal*, Nos. 382, 383, 384, 385, 1868.)

2. *Address on the Relation of Food to Work done by the Body; and its bearing upon Medical Practice*. Delivered at the meeting of the British Medical Association, at Oxford. By the Rev. S. HAUGHTON, M. D., D. C. L. Oxon., F. R. S., etc. etc. (*British Med. Journ.*, Aug. 15, and 22, 1868.)

1. DR. JONES's lectures are devoted to the consideration of a somewhat recondite subject, but one of extreme importance, and which, if thoroughly investigated, especially in connection with that of the relation of food to work done by the body—a question ably treated by Dr. Haughton, and which will be presently noticed—must lead to a clearer comprehension of the operations of the animal economy, and give greater precision and efficiency to therapeutics. To fully comprehend the import of these discourses, more than ordinary attention may be required—they must be studied, not cursorily read—but we trust that no one will be deterred by this from undertaking the task, for those who accomplish it will be amply repaid for their labour.

In his first lecture, Dr. Jones points out the three stages which our ideas have undergone regarding the union of matter and force in the physical, or as he calls them, "the abiological" sciences.

The first or primitive stage is that of complete separation between the ideas of matter and force. He shows that before any knowledge of science existed, the ideas of force and matter were formed on superficial likenesses and distinctions, and that even to a late day our ideas of force or fire were entirely separable from our ideas of the three different conditions in which matter may occur—solid, liquid, and gaseous.

The second or transition stage of ideas consists in an incomplete separation between the ideas of matter and force. In this stage, force is considered as altogether separable from ponderable matter, but perfectly inseparable from an imponderable ether, or gas, or fluid, which is capable of being attached for a time to the imponderable matter. Dr. Jones traces the idea that force is imponderable matter to Kepler, who first started it, and presents the views subsequently entertained by Descartes, Leibnitz, Newton, Whewell, Young, Fresnel, Faraday, &c.

In the third, or modern stage, there is complete union, and no possibility of any separation between the ideas of matter and force. "The absolute union—the complete inseparability of our ideas of matter and force," observes Dr. J., "is most apparent in our ideas of matter and chemical force. A molecule has been endowed with a force which gives rise to its various chemical qualities,

and these never change either in their nature or in their amount. Mr. Faraday says, 'a particle of oxygen is ever a particle of oxygen—nothing can in the least wear it. If it enter into combination, and disappear as oxygen—if it pass through a thousand combinations, animal, vegetable, and mineral—if it lie hid for a thousand years, and then be evolved, it is oxygen with its first qualities. Neither more nor less. It has all its original force, and only that; the amount of force which is disengaged when hiding itself has again to be employed in a reverse direction when it is set at liberty.' (Faraday, *Researches in Chemistry*, p. 454.) If it were possible to take the ultimate atom of any one of the elements, we should find that the chemical force which constitutes and determines its nature, would be absolutely inseparable from the matter of which the element consists. For example, the ultimate atom of carbon would have the same kind of force as any mass of carbon, and it would differ in kind, and always from the ultimate atom of any other element, because of the peculiarity of its force. If the chemical force could be separated from the atom of carbon, the matter might cease to be carbon, and might become some other element, and the transmutation of metals might then be possible. The union, also, between matter and gravity is just as inseparable as the union between matter and chemical force. Matter without weight is not matter at all; the weight belongs to the matter, and cannot be taken from it. The gravity can no more be destroyed than the matter itself can be destroyed. However small the matter may be divided, yet each part will have a part of the force, and there can be no more of the force lost than of the matter. We cannot think that the matter can exist without the force of gravity being always acting or ready to act in each atom of it. Nor can we think that any portion of the force of gravity can be separated from the matter. If we mentally attempt to divide any amount of the force into its constituent portions, then every portion, however minute, of the force, must have a corresponding portion of matter to which it is inherent, and without which the force cannot be thought to exist.

"Newton's great discovery consisted in determining the existence of force in each particle of the matter of the earth and the planets; and Adams and Leverrier, recognizing the action of a force not accounted for in the matter that was known, predicted the existence of unknown matter in an undiscovered planet which was looked for and found. The great advance, however, towards the modern stage of ideas regarding the inseparability of matter and force, is owing to Young and Fresnel, who overthrew the second stage by their discoveries regarding light."

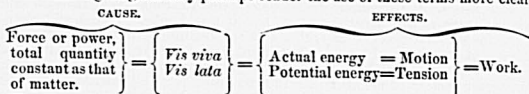
These discoveries, with the investigations of others in regard to heat, electricity, and magnetism, show that they as well as light, may be regarded as peculiar vibratory motions of ponderable matter, having quantitative relations to all other forms of motion.

"It must, however, be remembered," Dr. J. remarks, "that these three stages pass insensibly into one another; and that, in the history of these ideas in individual minds, some ideas regarding the separability of matter and force may be found in the third stage, while other ideas may still halt at the second, or never get beyond even the first stage which I have described. Thus every one may admit the inseparability of matter from the forces that cause gravitation and chemical action; whilst some may hardly be prepared even now to allow that heat is equally inseparable from matter. Still less readily may the cause of light be admitted to be inherent in ponderable matter; and few at present are able to believe that electricity and magnetism are peculiar motions, excited only in the molecules of ponderable matter. In other words, the third stage of ideas regarding the union of matter and force may to some extent be received by every one; but, in its full extent, it is only gradually becoming recognized as undoubted truth. As soon as it is admitted that force is absolutely inseparable from matter, whether gas, liquid, or solid, it will become as impossible to think that matter can consist only of centres of force, as to think that matter can be inert or void of all force. Matter must always be in a state of motion, or of tendency to, or of resistance to, motion; it can never be in a state of perfect rest."

Immediately connected with the idea of the inseparability of matter and

force, is another modern idea regarding force which is intended to be expressed first by the term conversion of force, and subsequently in succession by the terms correlation of forces, conservation of force, and lastly, by conservation of energy. This last term has been adopted in order to avoid the indistinctness and confusion which come from using the word force at one time as the cause of an effect, and at another time as the effect itself; and in order to confine ideas to the effect, which alone can be the object of experimental research. "Thus," observes Dr. J., "the word force, of the nature of which we know only that it is indestructible and inseparable from matter, is the cause of energy, and energy is the effect of force."

The following diagram may perhaps render the use of these terms more clear.



The idea of the conservation of energy is, that the sum of the actual and potential energy in the world is constant. The force, or, as it is better called, the actual energy, that can be put into the cannon ball, is exactly equal to the latent or potential energy in the gunpowder, and this depends on the chemical force in the oxygen, hydrogen, and carbon. The ball gains only what the powder loses. As the potential energy, or tension, decreases, the actual energy, or motion, increases, and no loss or gain in the total amount of motion and tension can occur. Whatever the form of motion may be, it can only come either from some other form of motion or from some form of tension.

"It has been Dr. Joule's great work to exhibit experimentally the measurable relation between heat and gravity. He has determined that a certain amount of one kind of motion does produce an equivalent quantity of another kind. He proved that 772 pounds weight of matter falling one foot gives rise to enough heat to raise a pound of water one deg. Fahr. in temperature. He called the unit of mechanical motion one pound weight falling one foot = one foot-pound, and the unit of heat that quantity which raises one pound of water one degree Fahr.; then the mechanical equivalent of heat is 772 foot-pounds.

"The equivalence of other forms of energy has yet to be determined by experiment. Meanwhile, according to modern ideas, the different forms are so related to one another, that none can be lost, and none can be produced except by passing into or out of some other form of energy."

Dr. J. sums up the present state of our knowledge in the abiological sciences regarding matter and force in the following formulæ: "Where matter is, there force must be, showing itself in motion, tension, or in resistance. Without matter, no kind of motion, nor tension, nor resistance occurs."

In his second lecture Dr. Jones considers the matters and forces in those sciences—the biological—in which the idea of life is concerned, and he shows that our ideas regarding the union of living matter and living force, have passed, or are passing through the same three stages that they have done in the physical sciences. Dr. J. shows by quotations from our oldest records that "in the earliest ideas of all nations and probably of all individuals, no doubt whatever exists as to the entire separability of the ideas of matter and of vital force; and the first stage of ideas in the biological sciences is identically the same as the first stage in those sciences into which the idea of life does not enter.

"As the *second* stage of ideas," he continues, "in the abiological sciences consisted in the assumption of an imponderable matter, which was considered to be separable from the ponderable matter, and diffusible through it, giving rise to the phenomena of force in every part; so the second stage, or partial separation in the ideas of living force and matter, is marked by the assumption of a living imponderable gas or fluid pervading the ponderable matter. This stage, from the renown of him who gave it the greatest support, may well be called the Hunterian stage."

The idea of a subtle æthereal fluid diffused through the frame, enabling it to show all the phenomena of life, was taught by Hoffman, whilst others assumed

that, instead of a single vital fluid capable of doing all work, there were many different vital fluids, each capable of doing its own work and no other. The most remarkable of these was the nervous fluid.

"Another very remarkable vital fluid was considered to be a chemical agent, an elementary principle, or highly attenuated substance, which, among its other singular and remarkable properties, has that of imparting to the constituent matters of the animal frame new chemical affinities between it and the surrounding elements, and thereby protecting the living fibre from dissolution, or giving them other properties which, without this vitalization, they would not possess."

"The progress of animal chemistry," Dr. J. very justly observes, "proves more and more clearly that the matter in the body has no special chemical properties peculiar to life; but that matter within possesses the same chemical energy which it possesses out of the body. Life has no power to create or destroy any chemical force in the matter of living things; but the very slightest difference in the circumstances under which any chemical action occurs, produces a variation in the effects that are produced. Ultimately, when all the circumstances under which vital chemical actions occur are fully made out, there will be found to be no difference between these actions and those which can be made to take place where no influence of life can be supposed to exist."

"Another vital fluid, or principle, has been assumed to account for the phenomena displayed at the beginning of life in animal and vegetable bodies. Dr. Prichard says: 'This vital principle assumes the character of a plastic or formative power. It presides over, and sets in action, the different processes by which growth and organization are effected, and gives form and modification to the exponent parts of the animal and vegetable body, and contributes afterwards by a preserving influence to the maintenance of its existence for a definite portion of time. This doctrine ascribes to a thing which is supposed to be merely a species of matter—highly attenuated, properties and agencies which belong to the highest power and the highest intelligence.' It appears, then, that, in the biological as in the abiological sciences, ideas of the union of matter and force have gone, or are going, through two identical phases. As in the abiological sciences the earliest ideas of matter were quite separate from the ideas of force, so vital force, in the first stage of our ideas, was originally pure spirit, void of all materiality, perfectly separable from matter."

In his third lecture, Dr. Jones shows that the third stage of ideas regarding the union of matter and force is growing up, and that it gives promise of fruit far beyond any we have hitherto gathered in physiology, pathology, and therapeutics.

"The general ideas regarding the union of matter and force in the biological sciences, have not as yet," Dr. J. observes, "got beyond the second or Huxleyian stage; and there are many who think that the first stage, which consists in the complete separability between matter and living force, still represents the whole truth. The third stage, or complete union between the ideas of matter and living force—that is, the utter inseparability of one particle of living force from the matter in which it has been placed, is as yet in its infancy, and cannot be yet subjected to the examination it will have to undergo."

"We are only just entering upon the inquiry how far our ideas of conservation and correlation of energy can be extended to the biological sciences. We are only just beginning to ask how far a balance can be struck between the income and outgoing of all the energy which vegetables and animals possess in health and in disease. The quantity and quality of the energy that comes in, and the quantity and quality of the energy that goes out of the living thing, are questions in every respect as inseparable from the progress of biology, as the quantity and quality of the matter that enters into or is thrown out of any system. The slight progress that has hitherto been made is seen in the fact that there are many persons at present able to rest in the belief that the inseparability and conservation of matter and force are our main principles and our best guides in the abiological sciences; whilst most persons think that in the biological sciences the perfect or imperfect inseparability of matter and force, and the constant creation and annihilation of energy, are most likely to be the true foundations on which the sciences that include life must be built. But, if this be

so, then the creation and annihilation of force must be established by positive proof, and must not rest only on assumptions which are directly opposed to the most certain knowledge we possess regarding matter and force in other branches of science.

"We know now that in all living things no separate or peculiar matter is present. The stuff which takes part in the living actions, and the forces which are inherent in that stuff are there, and indestructible and inseparable. Inorganic matter and inorganic force always exist together in living things; so that, if a separable living force be also present, then we must admit that two totally different laws of force must be in action at the same time in the same matter. The unity of nature will at least be preserved by our hesitation to admit the assumption of a force capable of creation and annihilation, until some very conclusive evidence be obtained that there actually is in living things such a force or forces capable of being separated entirely from the matter of which they are made. Until this be proved, let us inquire how far the third stage of ideas regarding the union of matter and force and the principle of the conservation of energy opens new paths for investigation, and gives us new glimpses of truth. What are the actual and potential energies which enter into the body? To what motions do these energies give rise there? How do these motions leave the body? Matters in a state of tension, and ready for chemical motion, are constantly going into the body in the food and air. The quantity of active and latent energy which goes in, ought exactly to balance the quantity which comes out, deducting that which remains latent in the chemical substances, or becomes active in the actual warmth of the body itself. The chemical changes in the matter within the body (that is, the decrease of potential energy or tension) give rise to different forms of motion. These motions appear as the functions or work of the body. Two chief kinds may be distinguished—first, motion in great mass, as mechanical work, etc.; secondly, little mass, or molecular motion, as heat, electricity, nutrition, etc. A little mass of carbon and of oxygen contains a certain amount of tendency to move, that is, of potential energy. These molecules, as soon as they can, move together, and the motion produced must continue in some form until a state of tension or potential energy again results. The latent force of the nourishment is most easily measured by determining the amount of latent heat which the food contains. In order to do this, a known amount of substance is burnt, and the amount of heat produced is determined; and as the mechanical equivalent of heat is known, the equivalent amount of work which the substance can do may be calculated. By far the greater part of the potential energy or tension which goes in is ultimately changed into warmth. Other modes of motion, as electricity and mechanical work, take but a small part of the total income. The balance-sheet at present can give an idea of the form which the account will ultimately take; but it cannot tell the items with any approach to accuracy. The difficulties which surround the determination of these items at present may be seen by looking for a few moments where our knowledge now is regarding the origin of muscular motion.

"According to the earliest ideas, muscular motion was produced by the soul. According to transition ideas, the motion was considered to be created by a definite something, a vital force or fluid, capable of being increased or diminished according as stimulants (nervous or other) acted on it or not; and finally, capable of quitting the matter of the muscle a short time after the body was dead. The Hallerian irritability was the best representative of this stage of ideas. According to the latest ideas, the origin of the motion must be some antecedent equivalent motion. This is looked for in the chemical changes in the nitrogenous or the non-nitrogenous matter of the contractile texture or surrounding blood. 'No one,' says Dr. Frankland, 'possessing any knowledge of physical science, would now venture to hold that vital force is the source of muscular power. An animal, however high its organization, can no more generate an amount of force capable of moving a grain of sand than a stone can fall upwards, or a locomotive drive a train without fuel.' Professor Liebig and Playfair, and others say, that the chemical changes in the nitrogenous matter of the muscles are the cause of motion. Professors Frankland, Fick, and others

say that the mechanical work is much greater than can be accounted for by the amount of change in this matter, as measured by the urea produced. They determine the amount of mechanical work done in a given time, and they translate it into its equivalent of heat, weighing also the urea produced in that time. By burning a known weight of muscle out of the body, they determine how much heat it can produce; and from this they can calculate how much muscle must be burnt in the body to give an amount of heat equivalent to the mechanical work done in the given time. They then calculate what amount of urea this weight of muscle would produce. By comparing the actual amount of urea produced with the calculated amount, it appears that only one-fifth of the work can come from chemical change in the nitrogenous texture of the muscles. Four-fifths of the work must arise from the chemical action going on in the non-nitrogenous matters in the muscles or in the surrounding blood.

"The experiments made by Dr. Parkes most completely confirm the view that the motion of the muscle during exercise does not bear any relationship to the amount of chemical disintegration in the albuminous substance of the muscle. Indeed, he suggests the opinion that the action of the muscle is not connected with disintegration, but with formation; that, when it is in exercise, it increases; and, when it is quiescent, it lessens in bulk; that is, that it more rapidly disintegrates during rest than during exercise. This view can only be proved by a vast amount of further experimental research.

"When this question, which regards the value of this one item in the expenditure and income of matter and force, is solved by experiment, there will be left still more difficult problems—as, for example, how this conversion of heat into contraction of muscular fibre takes place; how the nerves are made to be able to increase or lessen the conversion of latent into active energy at will. This most extensive and important inquiry, which the doctrine of the conservation of energy has opened to our work, is good evidence that the third stage of ideas on the union of matter and force is beginning to be received in physiology.

"What the worth of these ideas is may be seen in the comparatively simple problem of the source of animal heat, when the doctrine of the conservation of energy is admitted. Whether animal heat arises from nervous force or from chemical action has been a point as disputed as whether voltaic electricity arose from metallic contact or from chemical action. The dispute is ended in both instances by the admission of the doctrine of the conservation of energy. If the animal heat comes from nervous force, or the electricity from metallic contact, then what is the equivalent of potential energy that gives these their actual energy? Unless the creation of force be assumed, the equivalent in actual or potential energy must be forthcoming. In the case of animal heat, it may be said that the nervous force comes from an equivalent energy of nutrition; but then the further question must be answered: Whence does this energy of nutrition come? And this brings us ultimately to the chemical force which gives the potential energy to the matter that enters the body. This is the prime-origin of the motion which we call animal heat.

"The different kinds of apparatus or organs which the animal possesses for the conversion of energy determine in what form of motion the expenditure of energy can take place. The brain, the nerves, the muscles, the electric organs, the textures in general, all these are machines set in action chiefly by the potential energy or tension in the food, textures, and air; the supply of oxygen, hydrogen, and carbon being the first necessary condition.

"The mechanical, chemical, nutritive, muscular, and nervous motions are so related, that it is most difficult to separate the action of any one motion, even the simplest which can occur in the human body. When these motions are so increased or diminished as to constitute disease, then the difficulty of isolating any one motion becomes by no means lessened. Still, even in disease, the doctrine of the conservation of energy can enable us to make at least as great an advance as was made in our ideas and language when the doctrine of phlogiston, or the hypothetical inflammable principle which was thought to possess a power of levity, was given up.

"Vital force in disease must cease to be regarded as an imponderable material capable of varying in quantity and quality. It cannot be made more active

by stimulants, or be kept up by whips, whether ponderable as alcohol, æther, ammonia; or imponderable as heat, light, electricity, friction; nor is it capable of being made less active, or let down or untuned by excessive use or by withdrawal of the stimulants.

"When any excess of motion takes place, we must have an answer where the equivalent of that motion comes from, and whither it will go. Our ponderable and imponderable whips and stimulants are bound up with the matter, and produce more active motion according to the latent energy which the matter itself possesses. When any want of motion occurs, we must ask whence the deficiency of motion comes. Is there a want of matter possessing latent energy? or is there increased resistance to the conversion of latent energy into active motion?

"It may be said that this is only a verbal alteration; but it is, in truth, an alteration in the foundation on which our knowledge is based. It is an alteration which represents the direction in which science is advancing; and it is an alteration which not only marks the advance, but renders further progress more certain and more easy."

Dr. J. illustrates the importance of the change in our views regarding the union and conservation of matter and force by the phenomena of inflammation, and observes: "The principle of the conservation of energy requires that increased oxidation and nutrition in the inflamed part cannot arise except from an equivalent quantity of some form of motion, or some form of potential energy reaching the part. The same principle also requires that the inflammation must continue until the increased motion passes off in heat, or in pus, or in some other form of motion. Thereby the increased motions subside to the amount which is called health.

"The doctrine of the conservation of energy and the inseparability of matter and force will lead to an entire change not only in physiology and pathology, but also in that most practical part of medicine, therapeutics. At present, our knowledge is very confused and uncertain as to how and where medicines act. We almost believe that our medicines have the power not only of creating, but of annihilating force; and we almost think that they are able to select the part on which they will act, whilst they leave other parts of the body entirely free from their presence. From our want of knowledge how and where the effects are produced, the greatest possible difference of opinion exists as to the action and work of all the different classes of medicines—stimulants, sedatives, tonics, alteratives, specifics, evacuants. We are almost led to say that stimulants create force, because they increase contractility and sensibility; that sedatives destroy force, because they diminish contractility and sensibility; that tonics create force, and specifics destroy force, and alteratives change force. But the law of conservation of energy requires us to believe that no food and no medicine can cause the creation or the destruction of the slightest particle of energy. The amount of conversion of potential into actual energy may be made more or less. The conversion of one kind of motion into another kind may be diminished or increased, but no annihilation nor creation of force is possible.

"We must cease to regard the so-called imponderable heat, or its opposite cold, friction, or its opposite rest, electricity, light, etc., as entities that can be increased or diminished as remedies; and we must begin to look at them as modes of motion of the particles of matter in the different parts where they act. These modes of motion, by their correlations with the motions of oxidation and nutrition which are going on in the affected part, determine whether more motion or less motion should result.

"The medicines which are taken into the body have the same incapability as food to create or annihilate force; but they possess chemical energies by which, wherever they go, they take part in the motions of oxidation and nutrition which are going on there; and, according to their chemical properties, they add to the motions, or increase the resistance to the motions that constitute disease.

"The questions, then, which must be answered before we can obtain clear ideas of the actions of medicine in the body are: 1. What are the different motions which occur in the body? and how are these different motions related

to one another? and 2. How do different agents or medicines increase or diminish these different motions which occur in the different organs and textures?

"Assuming that any energy which shows itself in any of the motions of the body must arise from some other form of energy, and that this must ultimately be traced up to the chemical energy which enters with the food and air, then the action of medicines in increasing or diminishing or altering the action of oxygen in the different textures must be at least one of the most important questions in therapeutics."

Dr. J. illustrates these views by the action of acids and alkalies, which he shows are capable of taking a part in oxidation, and refers to his own experiments and those of Dr. Dupré, showing the rapidity with which certain medicines pass into every texture of the body (see No. of this Journal for July, 1865, p. 202), and maintains that they carry with them whatever force they possess, and thence infers that our present ideas of the local action of medicines are far too restricted.

"From these glimpses," he says, "into the physiology, pathology, and therapeutics of the future, each of which might well have been the subject of many lectures, it is evident that a great change will take place in our ideas in the biological sciences when we follow the progress of knowledge in the abiological sciences. As the abiological sciences have passed, or are passing, through three different stages of perfect and imperfect separation and perfect union of ideas regarding matter and force; so it is reasonable to expect that ultimately we shall pass through the same three stages of ideas regarding the union of matter and force in the biological sciences; and, if so, we shall arrive at an idea of life which will be based on the perfect union of matter and force.

"If biology be disposed to profit by the progress of the other sciences. we must endeavour to search for vital force, as the most peculiar of all the motions of which matter is capable. It must be able to arise from other motions and be able to give rise to other motions; and it must be altogether as incapable of destruction and creation as the abiological forces themselves. It may well be said, what can be the nature of this motion? how can it be understood? The answer must be the same as that which we must give even now regarding the nature of the motion of the simple or compound atoms of matter which we call electricity or magnetism, or even light or heat. How many among us at present have a clear idea of the motion of the simple molecules of matter which we call heat, or even gravitation and crystallization? Whilst we are unable to grasp the marvellously complex double polar motion of compound molecules which constitutes electricity, can we expect to be able to form an idea of the most complex of all the motions of matter from which the mind turns away to the image of some ærial or æthereal spirit, with large wings and larger powers; or rests satisfied with an imponderable gaseous or liquid matter diffused through living liquids, or temporarily attached to more solid granular matter?

"Notwithstanding our ignorance, let us attempt to gain knowledge by following in the footsteps of the abiological sciences. Whatever form of motion or tension proceeds from the body, let us regard it not as created or destroyed, but as the representative and equivalent of that energy which went into the body. Let us consider that the balance of in-going and out-coming energy of the body is exactly comparable with the balance of the in-going and out-coming matter; and let us remember that these balances are inseparably dependent the one on the other."

2. Dr. S. HAUGHTON, in his eloquent address, presents some highly important views on the subject of the *relation of food to work done by the body*. "It is admitted," he observes, "that man and other animals possess a double life, *animal* and *organic*, presided over respectively by two distinct, though correlated, centres of nervous force; of these, one *thinks, moves, and feels*; the other merely *cooks*, receiving the food supplied, changing and elaborating it into elements suitable for the use of the animal life." And he further observes, that "it is a simple matter of fact, and of every-day observation, that all these forms of

animal work, are the result of the reception and assimilation of a few cubic feet of oxygen, a few ounces of water, of starch, of fat, and of flesh.

"During childhood and youth, the food that we eat is used for the double purpose of building up the tissues of the bones, the muscles, the brain, and other organs of the body; and of supplying the force necessary for work done, whether mechanical or intellectual. In adult life, the first use of food almost disappears, for the bones, the muscles, the brain, and other organs, have already reached their full development, and act simply as the media of communication between the food received and the work developed by it.

"Let us take, as illustrations, the muscles and brain, regarded as the organs by means of which mechanical and intellectual work is done. These organs resemble the piston, the beam, and the fly-wheel of the steam-engine, and, like them, only transmit or store up the force communicated by the steam in one case, and by the products of the food conveyed by the blood in the other case. The mechanical work done by the steam-engine must be measured by the loss of heat experienced by the steam in passing from the boiler, through the cylinder, to the condenser; and not by the loss of substance undergone by the several parts of the machinery on which it acts. In like manner, the mechanical or intellectual work done by the food we eat is to be measured, not by the change of substance of the muscles or brain employed as the agents of that work, but simply by the changes in the blood that supplies these organs—that is to say, undergone by the food used, in its passage through the various tissues of the body, before it is finally discharged in the form of water, carbonic acid, or urea. * * *

"The food consumed in twenty-four hours, including air and water, undergoes a series of changes of a chemical character before leaving the body, in the form of one or other of its excretions. Some of these changes develop force, and others expend force, but the algebraic sum of all the gains and losses of force represents the quantity available for work. This work must be expended as follows: 1. The work of growth (*secular*). 2. The work of maintaining heat (*periodic*). 3. Mechanical work (*periodic*). 4. Vital work (*periodic*).

"During childhood and youth the work of growth is positive, for a certain proportion of the food used is employed in building up the tissues of the body instead of being expended in actual work; it is, in fact, 'stored up' in the body, as *vis viva* is stored up in the fly-wheel of machinery, and constitutes a reservoir of force that may be called upon at an emergency requiring sudden expenditure of force, or in case of illness, or in the gradual wasting of old age.

"In adult life, and in old age, the work of growth ceases completely, except so far as it is necessary to repair, from day to day, the small wastes of the organs employed in work; so that nearly the whole of the food employed is expended on the *periodic* work of the body.

"Hence we can readily see the reason for the aphorism, which asserts that food is more necessary for the young man than for the old, and more required by those of a lively disposition, either of mind or body, than by others."

It was demonstrated by Lavoisier that the source of animal heat is to be found in the combustion of the carbon of the body by the oxygen of the air received into the lungs by respiration.

"As soon as it was satisfactorily established by Lavoisier and his successors that the natural combustion of carbon and hydrogen in the blood was sufficient, and rather more than sufficient, to account for the animal heat, it became a matter of great interest to physiologists to ascertain, if possible, how much of the work developed in the blood by chemical changes is employed in producing animal heat, how much in mechanical work, external and internal, and how much in vital or mental operations."

From numerous observations, some of which were made by Dr. Haughton on the daily labour of hodmen, paviors, navvies, and peddlers, he has obtained the following mean:—

"Daily labour of man=353.75 ft. tons.=109549 kilometres.

"This quantity of work is the exact equivalent of the work done by a man of 150 lbs. weight in climbing through one mile of vertical height, and is, as I have already shown, less than one-eighth part of the work expended in producing and maintaining animal heat.

"Even if we add to the external muscular work that of circulation and respiration, which may be estimated at 133 foot-tons, the whole work done by the muscles, voluntary and involuntary, of a hard-worked labourer will amount to less than one-sixth of the work expended in maintaining the temperature of his body at 100° Fahr.

"I was led to believe, from my investigation as to the quantity of urea excreted in various diseases, that a certain minimum quantity equivalent to 2 grs. per pound avoirdupois of body weight, was excreted quite independently of muscular exertion, and I proved that death was preceded in many chronic diseases by a fall in the urea excreted to 2 grs. per pound. These investigations were made chiefly on patients dying of advanced kidney disease, in which the excretion of albumen had nearly or altogether ceased, and on patients dying of phthisis."

"If these views," says Dr. H., "be well founded, it is plain that part only of the urea excreted can be regarded as due to muscular exertion, for 2 grs. per lb. (or 300 grs. for a man weighing 150 lbs.) must be set aside as a constant due to vital work, independent of muscular work altogether. Hence it would follow, supposing the muscular exertion to be measured by the increased excretion of the urea produced by it, that the urea will not increase as fast as the muscular exertion, but it ought to increase regularly, although at a slower rate."

To settle this important question, Dr. H. ascertained by repeated experiments, that the amount of his own excretion of urea (under ordinary conditions of exercise, which did not exceed five miles per day) ranged from 465.09 grs. per day to 537.47 grs., the mean being 501.28 grs. He then compared this with the average found from several days of unusual muscular exertion. The average work done each day, for five consecutive days, was 20.74 miles of horizontal walking, "the result of which upon the urea excreted was to be compared with the result already mentioned, as a physiological constant determined under circumstances in which the daily muscular work never exceeded five miles of horizontal walking."

In order to determine the urea, he collected all the urine passed, and kept one-fifth part of it; and at the close of the fifth day examined the mixture formed from the five days' urine. It was found to contain 501.16 grs. of urea per day—a result identical with the physiological quantity previously found by him under totally different conditions, viz., 501.28 grains.

"It might be objected," Dr. A. remarks, "to the preceding reasoning that there can be no doubt as to the capability of the combustion of proteinic compounds represented by 501.28 grs. of urea excreted to produce mechanical force sufficient to explain the muscular exertion of walking 20 or 21 miles per day, as may be shown in the following manner:—

"1. The urea excreted bears to the proteine consumed the proportion of 24 to 79, as appears from their chemical compositions, viz.—

Urea . . .	$C_2H_4N_2O_2$	. . .	60
Proteine . .	$C_{26}H_{27}N_4O_{12}$	. . .	395

"2. In 100 parts of proteine there are 53.7 parts carbon, and 7 parts of hydrogen; the total heat due to the combustion of 1 grm. of proteine is, therefore,

	Heat-units.
0.537 gramme of carbon	4.3389
0.070 gramme of hydrogen	2.4123
	6.7512

"This number, 6.7512, represents the maximum quantity of heat units¹ that could be produced by the combustion of 1 grm. of proteine; but the term depending on hydrogen in it should be reduced to $\frac{1}{5}$ ths of its amount in consequence of the hydrogen already combined with oxygen in the proteine. Hence we find—

¹ Heat unit = 1 kilog. of water raised 1° C. .

Combustion of 1 gramme of Proteine.

	Heat-units.
Carbon	4.3389
Hydrogen	1.3402
	5.6791

"3. In 100 parts of urea there are 20 parts of carbon, and $6\frac{2}{3}$ parts of hydrogen; the total heat, therefore, due to the combustion of 1 grm. of urea is—

0.20 grm. carbon	1.6160
0.067 grm. hydrogen	2.3089
	3.9249

"The term depending on hydrogen in this result, should be reduced to $\frac{1}{2}$, in consequence of the hydrogen already combined with oxygen in the urea.

Hence we find—

Combustion of 1 gramme of Urea.

Carbon	1.6160
Hydrogen	1.1544
	2.7704

"4. From the three preceding statements it is easy to see that, for every gramme of proteine consumed, 0.8416 heat-units are contained in the urea excreted; so that the digestion of 1 grm. of proteine gives out 4.8375 heat units.

"It is easy to see that 501.23 grs. of urea excreted correspond to 1650 grs. of proteine in the food, or to 106.92 grms.; and the total work due to the digestion of this quantity of food may be found by multiplying it by the 'digestion coefficient' already found, and by 423, which is Joule's coefficient for converting heat-units into kilogrammeters. Hence we have—Work due to production of 501.28 grs. of urea= $106.92 \times 4.8375 \times 423 = 218786$ k. m.=704 ft. tons.

"This amount of theoretical work produced by nitrogenous food is more than double the work actually done during the walking excursion.

"The average work was 20.74 miles horizontal per day, which may be considered as the exact equivalent of lifting my weight (knapsack and clothes included=150 lbs.) through one mile of vertical height. Hence the work actually done by me was

$$\frac{150 \times 5280}{2240} = 354 \text{ foot-tons.}$$

"I have elsewhere shown that the work done by the heart per day amounts to 122 foot-tons, which should be added to the external work, as well as the unknown work due to the muscles used in respiration, probably amounting to one-sixth of the heart's work, or 21 foot-tons; adding these quantities, we find—

External work	354 foot-tons.
Circulation and respiration	133 "
	487 foot-tons.

"This quantity represents 69 per cent. of the applied work, which was shown to be 704 foot-tons.

"The amount of muscular work accounted for is 354 foot-tons, which is almost exactly half the whole theoretical work supplied by the food that goes to form urea, viz., 704 ft. tons; but it has been already shown that 2 grs. of urea per pound of body weight is required to maintain the vital work, including circulation and respiration; this would give from 240 grs. to 260 grs. of urea out of the 501 grs. available for vital work, so that one-half of the available work may be considered as expended on vital work, and the other half as expended on external muscular work. This supposition, however, requires us to believe that the muscles act without loss by friction. This is not admissible, for I have elsewhere endeavoured to show that there is a loss in the force applied by the

muscles of various animals in consequence of the friction of their tendons, amounting—

In man to	35 per cent.
In the mastiff to	41 “
In the kangaroo to	61 “

“Hence it may be regarded as certain that the available force represented by 501 grs. of urea is not sufficient to account fully both for vital work and for the external mechanical work expended by me during the experiments just described.”

Liebig and his followers assigned to nitrogenous food the duty of providing the force necessary for the production of muscular work, by supplying the waste of muscular tissue, which waste was supposed to be represented by the urea of the kidney secretion; while they supposed the farinaceous and fatty foods to provide the amount of animal heat required by the body; while their opponents deny that nitrogenous food contributes any portion of the force employed in muscular work. “The truth,” Dr. H. says, “as is usual, lies between the two extreme hypotheses, and we are now compelled to admit that a given development of force, expressed in animal heat, muscular work, and mental exertion, may be the effect of several, perhaps many, supposable supplies of digested food, farinaceous, saccharine, fatty, and albuminous.”

Lavoisier supposed, in his earlier investigations, that animal heat was developed by the combustion of carbon and hydrogen in the lungs, while Liebig and his followers supposed the muscular waste to be developed in the substance itself of the muscles which were its instruments. Both these doctrines are now repudiated by physiologists, and the view proposed by Mayer, of Heilbronn, has been accepted, that the blood itself is the seat of all the chemical changes that develop force in the body. “No two classes of animals,” observes Dr. H., “can well differ more from each other than the cats and ruminants, one of which is intended by nature to eat the other. They differ in all respects as to food, the cats requiring a supply of fresh meat and blood for their health, and the ruminants being exclusively vegetable feeders; yet in both classes we find a great development of muscular power and of rapid action of the muscles, qualities alike necessary to the pursuer and to the pursued. There can be no doubt that muscular work is developed in the cats from the combustion of flesh, and in the ruminants mainly, if not exclusively, from farinaceous food. It is, however, worthy of remark that the muscular qualities developed by the two kinds of food differ considerably from each other. The hunted deer will outrun the leopard in a fair and open chase, because the work supplied to his muscles by the vegetable food is capable of being given out continuously for a long period of time; but in a sudden rush at a near distance the leopard will infallibly overtake the deer, because its flesh food stores up in the blood a reserve of force capable of being given out instantaneously in the form of exceedingly rapid muscular action. In conformity with this principle, we find among ourselves an instinctive preference given to farinaceous and fatty foods, or to nitrogenous foods, according as our occupations require a steady, long-continued, slow labour, or the exercise of sudden bursts of muscular labour continued for short periods.”

A number of examples are given by Dr. H. in illustration of this principle, which we have not space here to insert.

In conclusion Dr. H. shows the application of theory to diseased conditions of body, and takes as examples, 1, typhus fever; 2, cholera Asiatica; 3, diabetes mellitus.

1. In *typhus fever*, he observes, “a prominent symptom is the remarkable elevation of temperature, accompanied by an increased excretion of urea and carbonic acid by the kidneys and lungs, indicating (as no food is taken) an increased morbid metamorphosis of the blood and tissues. The temperature frequently rises to 104° Fahr., representing an increase of upwards of 5° Fahr. above the normal temperature.

“If we knew the cause of this increase of temperature, or rather of the increased metamorphosis of which it is the sign, we should know the cause of

typhus fever, and learn to combat the disease on rational grounds. At present the cause is unknown, and therefore the physician is forced to treat the symptoms as they appear, instead of attacking the cause of the disease. Let us examine for a moment the terrible significance of the symptoms.

"Your patient lies for nine or ten days, supine, fasting, sub-delirious, the picture of weakness and helplessness; and yet this unhappy sufferer actually performs, day by day, an amount of work that might well be envied by the strongest labourer in our land.

"The natural temperature of the interior of the body is 100° F., while the temperature of the corresponding parts in typhus fever is at least 105° F. This seems at first sight a small increase—only five per cent. of the whole; but it is in reality $2\frac{1}{2}$ times as great as it appears, and actually amounts to $12\frac{1}{2}$ per cent., or *one-eighth* part of the total animal heat. For the total quantity of heat given out by the heated body is proportional (from Newton's law of cooling) to the elevation of its temperature of equilibrium, towards which it tends. If we suppose this equilibrium temperature to be 60° F., then the quantities of animal heat given out in typhus fever and in health will be in the proportion of 45 to 40, showing that the animal heat of typhus exceeds that of health by *one-eighth* of its amount.

"We have already seen that the work due to animal heat would lift the body through a vertical height of eight miles per day; and it thus appears that an additional amount of work, equivalent to the body lifted through one mile per day, is spent in maintaining its temperature at fever heat.

"If you could place your fever patient at the bottom of a mine, twice the depth of the deepest mine in the Duchy of Cornwall, and compel the wretched sufferer to climb its ladders into open air, you would subject him to less torture, from muscular exertion, than that which he undergoes at the hand of Nature, as he lies before you, helpless, tossing, and delirious, on his fever couch.

"The treatment of this formidable disease in former times consisted of purging, vomiting, and bleeding the patient, with the view of eliminating an imaginary poison, and so helping nature to terminate the disease.

"In modern times, thank God, the physician either does not interfere at all, or adopts the rational process of retarding the disintegration of the tissues consumed to supply the fever heat, by furnishing in their stead fuel, in the form of wine and beef-tea, sufficient to maintain the increase of temperature imperiously required. This practice may be justly considered rational, because the condition of the circulation admits of its application, and it is considered good, because it has been rewarded with success in the hands of the skilful clinical physician. In concluding this sketch of the prominent symptom of typhus fever, and as an illustration of the eagerness with which every possible combustible in the body is made use of, I may mention, on the high authority of Dr. Stokes, of Dublin, that the very urea excreted by the kidneys is not permitted to leave the body without first paying its tax to fever, by being burned into carbonate of ammonia, thus rendering the urine of an advanced case of bad typhus fever eminently alkaline."

2. "*Asiatic Cholera* presents, as every one knows," Dr. H. remarks, "three distinct stages: 1. The premonitory stage of diarrhœa. 2. The stage of collapse. 3. The stage of consecutive fever.

"The stage of collapse exhibits the following symptoms: Vomiting or purging, muscular cramps, suppression of bile and urine, lowering of body temperature to 95° F., extreme prostration of strength, extremities pulseless, and face Hippocratic.

"When death occurs during collapse, the following symptoms are usually found on careful examination of the corpse: The temperature rises to 103° F., the muscles give out their characteristic susurrus CCC, and exhibit spontaneous movements, the whole train of symptoms producing the effect of a ghastly attempt at resurrection.¹

¹ "It is startling, on making a post-mortem examination of a cholera patient alone, and by candle-light, to witness, on the first free incision of the scalpel, the hand of the corpse rise slowly from its side, and place itself quietly across its breast."

"In this disease we have phenomena respecting animal heat, the very reverse of those found in typhus fever; the body performing one vertical mile short of its daily work, instead of one mile in excess. The prostration of strength resulting from this deficient combustion is so great, that death is often caused by bringing the patient to hospital in a cab instead of upon a stretcher, by his walking up a dozen steps into his ward; and sometimes even fatal results have followed a sudden effort to sit up in bed to vomit.

"The rise of temperature after death, and the continuance of muscular surrurs and motion, tend to prove that the impeded circulation, which is the prominent symptom in cholera collapse, is due to constriction (probably vasomotor nervous) of the capillaries, in consequence of which the muscles are deprived of their supply of freshly-oxidized blood, the result of which is necessarily contraction and cramp, which produces the excessive agony that characterizes this disease.

"All authorities on cholera, whether their object be to 'impede' or to 'assist' nature, are agreed that medicines, whether astringent or purgative, are not only useless, but dangerous, in the stage of collapse.

"It is useless to give alcoholic fuel to restore the loss of animal heat, for there is no circulation to cause the oxidation of the hydrocarbons. It is equally useless and more dangerous to give opium, to check the remaining purging that exists; for if vomiting have ceased, your acetate of lead and opium pills lie as if in the stomach of a corpse, and at the termination of collapse your patient enters upon the consecutive fever with perhaps a dozen grains of opium in his stomach, placed there like an explosive shell by your ill-timed zeal, and rapidly passes into a comatose condition, from which he never for a moment rallies. His death is always accredited by the registrar to cholera morbus, and not to opium.

"Purgatives and emetics¹ in cholera collapse effect the same object as opium, but with greater rapidity. In the stage of blue collapse the chances of life and death are almost exactly equal, and the slightest additional loss of force turns the wavering beam on the side of death. The effects of a brisk purgative or emetic (if they act) upon a patient unable to climb a dozen steps, or sit up for a quarter of an hour without fatal syncope, may be easily imagined; and the use of them cannot be justified by any arguments borrowed from right reason.

"A remarkable though transient improvement takes place in collapse by the injection of warm water (brought to the specific gravity of serum by the addition of mineral salts) into the veins or bowels; the patient loses the cramps, feels that he is about to recover, speaks to his friends, and often transacts whatever business is necessary, but speedily falls back into collapse. The improvement in his condition is altogether due to the temperature of the fluid injected, which supplies for a brief period the deficient animal heat, permits a partial oxidation of the blood, restores the capillary circulation in the muscles, and so destroys their cramp; and, by supplying the deficient work required, removes for the moment the fatal prostration of strength. Any one who has witnessed the remarkable effects of warm liquids thus injected in cholera collapse must feel that recovery would be certain if the improvement could by any possibility be made permanent.

"Our hopes for the future, as to the treatment of cholera, lie, as I believe, in the direction of supplying to the body directly its lost animal heat. I have witnessed the happiest results from an injection of warm salt water into the bowels, assisted by hand friction of the surface with turpentine and chloroform, and the application of bags of hot salt along the spine; in cases treated in this manner we may expect to witness cessation of muscular cramp, restoration of perspiration to the skin, with increase of capillary circulation, and finally, to reward our efforts, a return of the excretions of urine and bile; when these reappear, all vomiting and purging cease, and our patient is almost cured.

"After recovery, the contrast between the cholera and fever patient is as

¹ "When mustard is used, its conservative effects as a stimulant sometimes counteract its destructive effects as an emetic."

great as it was during sickness. The fever patient has been overworked for nine or fifteen days without a suitable supply of food, and, when convalescent, experiences a complete exhaustion of strength that lasts for many weeks. The cholera patient, on the other hand, has been prevented from working by constriction of the capillary vessels, caused by the absorption of the cholera poison,¹ and feels, on recovery, much like a man that has been half drowned, while the fever patient resembles a man that has been half starved; the one is able to return to his work in the course of a few days, the other, only after the lapse of so many weeks.

"There are two popular superstitions prevalent among medical men respecting nature, which yearly slaughter hecatombs of victims, viz., that nature is simple in her operations and beneficent in her intentions: she is often both simple and beneficent, but at other times she is unquestionably both complex and malevolent."

Before trusting Nature in cholera, and proceeding to help her. Dr. H. thinks it would be well "to inquire whether she intends to cure the patient by her evacuations, or to put him into his coffin. For myself, I greatly mistrust her, and would wish to ask, previous to assisting her, whether she is really my mother or only my stepmother. Our experience in Dublin has shown that no more effectual mode of shortening life could be devised in cholera than the 'eliminant' treatment; and it was accordingly abandoned as soon as tried in that city.

"It is much to be regretted that an authority so deservedly held in high repute as that of Sir Thomas Watson can be now quoted in favour of the treatment of cholera by the maxim *similia similibus curantur*. So far as Dr. Watson has informed us, his change of opinion rests upon the statements of others, and not upon his own experience. He has suddenly become an advocate of the castor-oil, rhubarb, calomel, and eliminant treatment of cholera, and writes as follows:—

"When I last spoke on this subject in these lectures, I stated that the few recoveries which I had witnessed had all taken place under large and repeated doses of calomel, but I could not venture to affirm that the calomel cured them. At present, I am much disposed to believe that, by its cleansing action, the calomel may have helped the recovery; and after all that I have since seen, heard, read, and thought upon the matter, I must confess that in the event of my having again to deal with the disorder, I should feel bound to adopt, in its generality, the evacuant theory and practice."

"Sir Thomas Watson omits to add that the cases here referred to were only six in number, of whom three died, and three recovered; which is exactly what might have been expected if he had not interfered at all."

3. *Diabetes mellitus*, according to Dr. H., "furnishes us with one of our best proofs that all the chemical changes, by means of which work is produced, take place in the blood and not in the tissues of the body; and, at the same time, an examination of its phenomena explains satisfactorily the regimen and diet which has been found, by experience, most suitable to the diabetic patient. I shall illustrate the disease by a case which was placed under my control, by Dr. Stokes, some years ago.

"A young man, aged twenty, named Murphy, suffered from fever (enteric?) in November, 1859, and, on recovering, became diabetic; he was admitted into the Meath Hospital in October, 1860, where he remained, under my observation, until his death on January 12, 1861.

"He was allowed for nine weeks to eat as much as he liked of certain kinds of food, which were varied, week by week, to suit his wants, my object being to obtain, if possible, the natural constants of the disease undisturbed by external interference; the only medicine used by Dr. Stokes's order being opium, to produce sleep, and a little creasote occasionally to promote digestion. As the details of this experiment have been fully published, I shall confine myself to the final results. His food and excretions were analyzed from week to week, so

¹ "Whatever this may be, its period of incubation is forty-nine hours; that of strychnia is twenty-two minutes."

as to determine the total quantities of sugar-forming and urea-producing food, as well as the sugar and urea actually excreted.

"During six of the nine weeks the sugar excreted was in excess of the sugar ingested, and the means of the daily excretion and ingestion of sugar were—

Sugar excreted	.	.	.	.	9773 grs.
Sugar ingested	.	.	.	.	9321 "

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"During two of the nine weeks of observation the urea excreted was in excess of the urea ingested, and the mean daily excretion and ingestion of urea were—

Urea excreted	.	.	.	.	1182 grs.
Urea ingested	.	.	.	.	1349 "

"The foregoing facts illustrate strikingly one of the prominent symptoms of diabetes—viz., the canine appetite—the quantity both of sugar-producing and urea-forming food consumed is more than double what is necessary to maintain a vigorous labourer in perfect health. An examination of the excretions explains the other prominent symptom of diabetes—viz., the complete prostration of strength in the patient, notwithstanding the great amount of food consumed.

"In a state of health, food produces three excretions only—viz., urea, carbonic acid, and water; in diabetes the farinaceous foods appear in the excretions as sugar, and not as carbonic acid and water; and the work necessary to maintain heat must be provided altogether at the expense of flesh food, which is the very form of food least fitted to maintain it.

"The diabetic patient resembles a racing steamboat on the Mississippi whose supply of coal is exhausted, and whose cargo furnishes nothing better than lean pork hams to throw into the furnace to maintain the race. It cannot be wondered at that our poor patient, under such disadvantageous conditions, fails to keep in the front.

"Let us compare together the minimum of work necessary to keep Owen Murphy alive with the work actually supplied to him by the food digested.

"1. I have already stated that Dr. Ranke found 660 grms. of carbonic acid in the extreme fasting condition, when he weighed 67 kilogrammes. Now, since

$$660 \text{ grammes} = 10185.35 \text{ grs.}$$

$$67 \text{ kilogrammes} = 147.71 \text{ lbs.}$$

we find 69 grs. per lb. of body weight as the minimum excretion of carbonic acid consistent with continued life.

"This quantity of carbonic acid represents a work generated by its production that would lift its corresponding pound of body weight through a height of

$$69 \times \frac{6}{22} \times 8080 \times \frac{9}{5} \times \frac{772}{7000 \times 5280} = 5.716 \text{ miles.}$$

"Under ordinary conditions, the greater part of this carbonic acid and work is produced by the digestion of farinaceous food; but since, as we have seen, the farinaceous food is excreted as sugar in the diabetic patient, and therefore does no work at all, the whole of the foregoing work must be done by the digestion of other kinds of food.

"I have already shown that it follows from Lavoisier's experiments (confirmed in a remarkable manner by those of Regnault), that the work done by the combustion of carbon in the body is to the work done by the combustion of hydrogen in the proportion of 9068 to 3024—almost exactly 3 to 1; hence we have the work done by Owen Murphy as a minimum in health.

Due to carbon	.	.	.	.	5.716 miles.
Due to hydrogen	.	.	.	.	1.905 "

$$7.621 \text{ miles.}$$

"This result is somewhat in excess of the truth, for the same reason that the

calculated digestion coefficient of proteine is in excess of that found by Frankland from experiment; for the combustion coefficients of carbon and hydrogen, in organic compounds, are slightly less than when free. If we are permitted to reduce 7.621 miles in the same proportion as in the digestion of proteine—viz., 48 to 43, we shall find—

Owen Murphy—minimum of work consists of body weight
lifted through 6.83 miles.

“Let us now compare this minimum with the work actually performed by him when suffering from diabetes, by the digestion of flesh food and production of urea.

“2. I have already shown that the work produced by the formation of 501.28 grs. of urea is 704 foot-tons by calculation from the composition of proteine and urea; this result should be reduced in the proportion of 48,375 to 43,155, in order to obtain the work given by Professor Frankland's experiments. Making this reduction, we find that 500 grs. of urea correspond to 626.3 foot-tons of work, or 100 grs. urea to 125.26 foot-tons; or, in other words—

“Every four grains of urea excreted correspond to five tons lifted through one foot.

“Owen Murphy excreted, on an average, 1182 grs. of urea daily during nine weeks, which, by the foregoing rule, are equal to

$$1475 \text{ foot-tons} = \text{Murphy} \times x;$$

where x represents in miles the height through which the patient could be lifted by the work done per day: and is equal to

$$x = \frac{1475 \times 2240}{93.66 \times 5280} = 6.69 \text{ miles.}$$

“This result is almost exactly equal to that already found as the minimum consistent with continued life, and explains in the most satisfactory manner the complete prostration of the patient, notwithstanding the consumption and digestion of more than double the usual quantity of flesh food.

“In corroboration of the foregoing conclusion, I may mention that Murphy's temperature was found to be constantly 2° Fabr. below that of other patients (chronic) placed in the same ward, and, in other respects, under similar conditions. His unfavourable symptoms (so long as his powers of digestion were not impaired) were invariably alleviated by the free use of flesh food and fat, the latter being instinctively preferred by him; so much so that during the delirium that preceded his death for twenty-four hours, he raved incessantly about ‘fat, roasted fat, which the angels of heaven were preparing for him.’

“I have studied many other cases of diabetes mellitus, and found similar results in all; but I feel it to be unnecessary to describe them, as one well-ascertained train of phenomena, carefully observed and recorded, is quite sufficient to establish the order of nature.”

While it may be perhaps, considered that Dr. H. has not fully accounted for all the phenomena of typhus fever, it must be admitted that he has most satisfactorily explained the prominent ones and corrected some prevalent erroneous notions. He has demonstrated that in patients lying in bed with typhus fever there is not, as has been supposed, a cessation of those processes which exhaust the bodily forces, but, on the contrary, that these processes are going on with unwonted activity—that the elevation of bodily temperature involves an expenditure of force greater than that consumed by a labourer in a hard day's work—and that consequently there is a peremptory demand for supplies of combustible food to maintain the oxidation of the tissues and to supply the force which could not otherwise be obtained, except at the dangerous expense of the tissues.

His explanations of the phenomena of cholera Asiatica and diabetes mellitus are of the highest importance, and constitute the most important and beautiful application that has been made of modern physiology to pathology and therapeutics. The correctness of his teachings must be assented to by all who carefully study these subjects.